3.2.5 Muon Trigger

Many of the important long-term physics goals in PHENIX require the collection of large data samples over extended periods of time at the highest available luminosities. We anticipate that a luminosity of $L = 8 \times 10^{26}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ for Au-Au and $L = 2 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for polarized proton beams will be reached over the next several years. In order to fully exploit the physics potential of the PHENIX detector at the highest luminosities achievable at RHIC it is important to further expand the data rate capabilities of the detector. In this section we discuss the upgrade of the first level muon trigger and a closely related upgrade of a new forward calorimeter covering the PHENIX muon arm acceptance. The principal physics goals of the upgrade are as follows:

- Flavor separation of quark- and anti-quark polarizations in the proton through the measurement of longitudinal single spin asymmetries for W-production in polarized proton-proton collisions. This measurement will require an upgraded momentum sensitive first level muon trigger and might require the addition of a nosecone calorimeter for the off-line separation of high momentum muons in W-production from background muons produced through hadron decays in jets (isolation from the jet-axis).
- Measurement of the gluon distribution at small x in photon-jet event samples using the combination of the present PHENIX central arm spectrometers and the future nosecone calorimeter. This measurement will be carried out in polarized p-p collisions and d-A collisions leading to a rich agenda of physics from nuclear effects on structure functions to the study of the gluon polarization at small x.
- Measurement of π^0 cross sections in the forward rapididity region $1.2 < \eta < 2.4$ in heavy ion collisions.
- Study of heavy quarkonium states at the highest obtainable luminosities in heavy ion collisions utilizing the momentum sensitivity of the upgraded muon trigger.

3.2.5.1 Performance of the Present Muon Trigger

We have used the proton data sample acquired in 2003 to evaluate the performance of the PHENIX muon trigger both using the present CAMAC based trigger processors as well as the custom build PHENIX trigger boards. We find background rejection factors between 100 and 200 for the CAMAC electronics and of about 250 for the custom trigger board. At the present collision rates of typically less than 50kHz in proton-proton collisions this has led to event rates of about 300 Hz in the single muon channel. This rate is compatible with the maximum expected bandwidth available for the first level trigger into the eventbuilder and second level trigger. We estimate the total usable bandwidth will reach 6-8 kHz and that a fraction of about 2 kHz can be used for the single muon trigger. The remaining bandwidth will be reserved for competing rare event triggers, eg. single electrons, di-leptons, high energy photons.

At the full luminosity expected for proton-proton collisions, $L = 2 \times 10^{32}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ leading to event samples of $\int Ldt = 800\,\mathrm{pb}^{-1}$ for a 10 week long physics run, the present first level muon trigger will count at rates of about 50 kHz or about a factor 25 more than the available bandwidth. The high background rate results from the large number of muons from hadron decays in jets. A data taking run of $\int Ldt = 800\,\mathrm{pb}^{-1}$ results in a sample of about 10000 W^+ and W^-. The limited size fo this data sample does not leave the option to solve the trigger bandwidth problem by random selection of a smaller sub-sample (pre-scaling). Instead it will be necessary to increase the selectivity of the muon trigger towards W-production. All proposed upgrade ideas exploit the difference in the momentum spectra for muons from hadron decay (background) and W-production (signal). The background muons mostly stay below momenta of 10 GeV while muons from W-decays have energies ranging from 10 to well over 100 GeV.

In addition to the collision related background discussed above the muon trigger has been found to be vulnerable against beam related backgrounds during the past proton runs at RHIC. The Collider Accelerator Department at BNL presently undertakes an effort to insert significant shielding in the beam tunnel upstream of the two PHENIX muon identifier walls in order to resolve this issue. However, in studying different upgrade proposals it is important to evaluate the performance of the proposed new muon trigger in presence of beam related backgrounds.

3.2.5.2 Trigger Upgrade Plans

Three possible solutions for the trigger upgrade have been studied. 1) The introduction of momentum information either from the existing muon tracker chambers or new dedicated trigger detectors upstream and downstream of the muon magnet. In the present version of the muon tracker electronics no information is send to the first level trigger processors. A significant re-design of the front-end electronics would be required in order to introduce muon tracker information into the level 1 trigger. 2) Utilizing threshold information from a segmented Cherenkov-counter to match muon roads from the muon identifier. 3) The use of a nosecone calorimeter to exploit topology differences between background jet production and signal events.

1) A complete GEANT simulation, including the performance of new trigger processor, has been carried out at UCR and BNL studying a new trigger using tracking information. In the simulation tracking information was provided either by a combination of muon tracker station one and a new dedicated detector downstream of the muon tracker magnet or a pair of dedicated trigger detectors up- and downstream of the muon tracker magnet. In both cases a angular resolution of 1 degree and a matching of the muon identifier road to the upstream track to better than 30 cm have resulted in the required muon trigger rejection in excess of 20000.

The simulation studies have led to an R&D program at Kyoto University and University of New Mexico which focuses on the possibility to read muon tracker information into the level one trigger processors. At UIUC the possibility of new dedicated trigger detectors is being studied. The R&D is funded through support from Kyoto University and the NSF grant at UIUC.

2) A Cherenkov detector, introducing a lower momentum cut-off, could be placed in the beam tunnel or between the muon arm magnets and the upstream muon identifier walls. The

integration issues in the north muon arm are difficult and are presently being investigated by collaborators at RBRC, BNL and RIKEN. GEANT simulations of soft electron background indicate that a modest segmentation, eg. 5 by 5 elements, would result in rejection factors of about 30. RIKEN and Kyoto collaborators have carried out an effort to survey the relevant backgrounds in the past RHIC run 2003. First results seem to indicate background levels significantly higher than the simulation results.

3) The nosecone electromagnetic calorimeter requires high segmentation and material with a small Moliere radius. Various solutions, including the usage of 20x20x200mm3 PbWO crystals with a 2.2cm Moliere radius are being studied at RIKEN, BNL, University of Colorado at Boulder and the University of California at Riverside.

The integration of the new trigger detectors will require a new set of local level-1 processors. A new regional trigger processor will combine and analyze the information from the local level 1 processors before passing the muon trigger decision to the PHENIX global level-1 system. Possible solutions are presently being discussed at Nevis and Iowa State University.

3.2.6 Schedule and Funding

We plan to complete simulation studies and the analysis of Cherenkov test data in December 2003. We will seek support for the PHENIX muon trigger upgrade through a collaborative NSF-MRI grant proposal to be submitted in January 2004. We have started to formulate the final scope of the upgrade project and the proposal writing. Groups at the Universities of California at Riverside, Colorado in Boulder and Illinois in Urbana Champaign consider to collaborate on the NSF proposal. At the same time RIKEN and Kyoto University have applied to Japanese funding agencies for support. Limited funds available for R&D from the NSF grant and internal funding at UIUC. Assuming a successful NSF grant application we aim at a first trigger integration stage based on prototypes in Fall 2006 and a completely installed and commissioned trigger in the Winter 2008.